Methodologies for environmental risks assessment related to the exploitation of energy geo-resources

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Abstract

The increasing exploitation of geo-energy resources to satisfy the needs of the world's population has also led to a focus on the risks associated with this type of human activity. It is in this context that this thesis is to be carried out with the purpose to study TechNa (Technological Hazard Triggering Natural Disaster) and NaTech (Natural Hazard Triggering Technological Disaster) events. The natural phenomenon that is a consequence of an industrial activity or acts as a hazard for the industrial accident is considered to be an earthquake. The entire thesis, carried out following a multidisciplinary approach, aims to provide a contribution to the development of methodologies for the assessment of environmental risks potentially related to the technological activities of geo-resources exploitation.

Three case studies and different specific methodologies are considered to explore a broad spectrum of analyses, i.e., the seismic characterization of an area, the statistical correlation between the industrial and seismic activity, and finally a multi-hazard risk assessment.

The TechNa event considered is the induced seismicity that is studied in the offshore area of Porto San Giorgio (Italy) and for the Cooper Basin geothermal site (Australia). In the first case, a probabilistic approach (Lomax et al., 2000) is used to relocate the 1987 Porto San Giorgio seismic sequence, which occurred in the Adriatic offshore near the Santa Maria a Mare hydrocarbon field. The ambiguity on the mainshock depth, already known in the literature, is solved by developing a technique that uses the macroseismic intensity field data based on a grid-search of the magnitude-depth space. The results show that the seismic sequence (about 30 events) developed in the first 15 km of the crust activating thrust faults and the mainshock has depth of 5.7 km and local magnitude equal to 5. Subsequently, to investigate whether there is a relationship between anthropogenic activity and seismicity, a statistical correlation analysis is carried out using the binomial and Mann-Whitney tests. It provides statistically significant values in correspondence with the 1987 Porto San Giorgio seismic sequence.

The second study on induced seismicity carried out in this thesis concerns the unconventional geothermal site of Cooper Basin. Unconventional techniques involve creating fractures for the circulation of fluids, but sometimes they can reach pre-existing faults by undesirable pathways, triggering strong earthquakes. In this work the relationship between technological parameters and the potential for seismicity to build undesirable pathways for fluid migration is investigated through a modern methodology (Lasocki & Orlecka-Sikora, 2020). A new parameter ZZ, degree of disordering of sources, quantifies this potential. It is calculated as the distance between seismic events in an eight-dimensional

space consisting of three hypocentral coordinates, T- and P-axis plunges, T-axis trend, and polar and azimuthal angles in the spherical system of coordinates beginning at the open hole of the Habanero 4 well. A Spearman correlation test is performed between technological parameters and ZZ showing that the higher the injection rate and wellhead pressure was, the less probable was the ability to create unwanted paths for fluid migration.

The third case study in this work is the analysis of a NaTech event. A multi-hazard risk analysis is conducted on the gas storage site of San Potito and Cotignola (Italy) simulating the failure of a pipeline generated by an earthquake and/or the material fatigue of the material. A bow-tie approach is followed to calculate the probability of occurrence of an accident, i.e., the leakage of gas from a pipeline. A Fault Tree is quantitatively solved using a new, very important tool, i.e., the MERGER application (Garcia-Aristizabal et al., 2019) available on the IS-EPOS platform (Orlecka-Sikora et al., 2020). Conversely, the Event Tree is only represented qualitatively.